JPL D-29204
MTO Product Assurance Requirements Document (PARD) for Mars UHF Antenna Array

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August 5, 2004

CHANGE LOG

DATE	Revision	SECTIONS CHANGED	REASON FOR CHANGE
July 12, 2004		All	Initial Draft Release
Aug 05,2004		Page 1 – Document # Page 2 – Change Log Section 3.3.11	Initial Release Page 1: Corrected document # on title. Is: JPL D-29204; Was: JPL D-28446. Page 2: Added "Revision" Column to Change Log 3.3.11 Software (S/W) Quality Assurance – Removed reference to Electra.

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	1.0 Introduction		
	1.1 Product Assurance Program		
	Product Assurance for the Mars Telecom Orbiter Mission(MTO) Project covers the disciplines of Contamination Control, Electronics Parts Engineering, Materials and Processes, Quality Assurance (Hardware and Software), Reliability Assurance, and Systems Safety. Imposed requirements also include the area of Environmental Requirements. A separate document establishes the environmental design and tests requirements.		
	1.2 Applicability		
	The requirements listed in this document are applicable to: (a) Contractor supplied hardware and software (b) Hardware and software designed and developed by JPL (c) Instrument Integration and Test (d) S/C Integration and Test (e) Launch support		
	1.3 Document Organization		
	This document lists the Product Assurance Requirements for MTO. The document is organized to: (a) Identify each requirement with an ID number (first column) (b) Describe the requirement (second column). Each requirement starts with “Requirement.” Descriptive information lacks the prefix of “Requirement.” (c) Provide a reference to find an explanation or data related to the requirement (third column). (d) Provide further explanatory comments regarding the requirement (fourth column).		

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	1.4 Definition		
	Critical Hardware: Flight hardware, flight spare, qualification model, engineering model, ground support equipment and other critical equipment that interface with flight hardware.		
	Critical Processes: are identified as those which affect the functionality, performance, or quality of the hardware and that failure to control these processes will result in significant risk to the end item.		
	Quality Records: are those records, which furnish objective evidence of activities performed or results achieved relating to the fabrication, assembly, integration and test of parts/hardware. Quality records include manufacturing planning records detailing specific steps performed, and inspection points; test logs and/or test documents detailing the test set up (temperature setting, dwell time, etc), test duration, and results achieved; records documenting non-conformances and the respective dispositions; corrective action records; calibration records; parts list for configuration management; and engineering and specification changes.		
	Controlled Documents: include test procedures, drawings, manuals, specifications, and other written documentation relating to the design, development, manufacture, and test of the hardware.		
	Flight Worthy Hardware and Software:		
	Mission Software Class : Flight Software (Class A) : Class A software is defined as mission-critical flight or ground software that is necessary either to assure mission success, or if it does not function as specified, that could cause loss of spacecraft, seriously degrade the attainment of primary mission objectives, or cause injury to humans or flight hardware. Examples of serious degradation of mission objectives include loss of a mission critical event, loss of science return from multiple instruments, or loss of a large fraction of the engineering telemetry data.		

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	2.0 Applicable Documents		
	The following documents of the issue in effect on the date of invitation for bids, or request for proposal, or product manufacturer, form a part of this document to the extent specified herein. In case of conflict, the conflicts shall be referred to the JPL MTO Mission Assurance Manager for resolution.		
	2.1 JPL Documents		
	o JPL D-1348, “ Standard for Electrostatic Discharge (ESD) Controls” o JPL D-8545, “ JPL De-Rating Guidelines” o JPL D-15032, “Category A Waiver Request/Approval ” o JPL D-53052, “Category B Waiver Request/Approval” o JPL QAP 144.1, “ Quality Assurance Material Review Board Action” o JPL D-19426, “Plastic Encapsulated Microcircuits (PEMs) Reliability /Usage Guidelines for Space Applications” o JPL D-5703, “ Reliability Analysis for Flight Hardware in Design” o JPL D-8208, “Spacecraft Design and Fabrication Requirements for Electronic Packaging and Cabling” o JPL D-8091, “ JPL Standard for Anomaly Resolution” o JPL D-14040, “ Process and Technical Guidelines for Spacecraft Hardware Project –Specific Environmental Assurance “ o JPL D-35492, “Standard Environmental Testing Facilities and Practices” o JPL D-10401, “ JPL Guideline for Reviews” o JPL D-560, “ JPL Standard for System Safety” o JPL STD-00009, “Flight Materials, Processes, Fasteners, Packaging and Cabling Hardware” o JPL FS511316, “Detail Specifications for Qualification of Critical Fasteners” o JPL DocID 61256,“Selection of Threaded Fasteners for Flight Applications” *JPL Adopted Documents* o International Space Station Document SSQ 25000, “ Destructive Physical Analysis (DPA) Requirements		

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	2.2 NASA and Military Documents		
	o NASA HDBK-7004, “ Force Limited Vibration Testing Handbook” o NASA-STD-7003, “Pyroshock Test Criteria” o NASA-STD-7001;” Payload Vibroacoustic Test Criteria” o NASA-STD-6001, “Flammability, Odor, Outgassing, and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion; Test 18, Arc Tracking” o NSS 1740.1NASA Safety Standard, “Guidelines and Assessment Procedures for Limiting Orbital Debris” o NPG 8621.1, NASA Procedures And Guidelines For Mishap Reporting, Investigating, And Record keeping (JPL Form 0554-S) o NASA-STD-8719.9, “NASA Standard for Lifting Devices and Equipment” o MIL-STD-461C; “Electromagnetic Emission and Susceptibility Requirements for the Control Electromagnetic Interference” o NPSL, “NASA Part Selection List” o MIL-PRF-38534, “General Specification For Hybrid Microcircuits” o MIL-STD-883, “ Test Methods and Procedures for Microcircuits” o MIL-PRF-19500,” General Specification for Semiconductor Devices” o QPL-19500, “Qualified Products List of Products Qualified Under MIL-PRF-19500, General Specification for Semiconductor Devices” o MIL-PRF-38535; “ General Specification for Manufacturing Microcircuits” o QML-38535, “ Qualified Manufacturers List of Microcircuits” o MIL-PRF-55365;” General Specification for Capacitor, Fixed, Electrolytic (tantalum), Chip, Non-Established Reliability, Established Reliability” o MIL-PRF-39003, “General Specification for Capacitor, Fixed, Electrolytic (Solid Electrolytic), Chip, Non-Established Reliability, Established Reliability” o MIL-STD-981, “Design, Manufacturing and Quality Standards for Custom Electromagnetic Devices for Space Applications” o MIL-HDBK-6870, “Inspection Program Requirements for Aircraft and Missile Materials and Parts” o MIL-STD-2175, Classification and Inspection of Castings”		

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	o MIL-HDBK-5H, “Metallic Materials and Elements for Aerospace Vehicle Structures” o MIL-HDBK-17A, “Plastics for Aerospace Vehicles/Polymer Matrix Composites” o SAE AMS-STD-1595, “Qualification of Aircraft, Missile, and Aerospace Fusion Welders” o JSC SP-R-0022A, General Specification Vacuum Stability Requirements of Polymeric Material for Spacecraft Application” o MSFC-HDBK-527/JSC-09604F, “Materials Selection List for Space Hardware Systems” o MSFC-SPEC-522B, “Design Criteria for Controlling Stress Corrosion Cracking” o SPI-4-11-8, “Selection of Threaded Fasteners for Flight Applications” o NASA TM-100351, : Material Selection Guidelines to Limit Atomic Oxygen effects on Spacecraft Surfaces” o NASA-STD-6001 Flammability, Odor and Off Gassing Requirements and Test Procedures for Materials in Environment that Support combustion” o NASA RP-1124; “Out Gassing Data for Selection of Spacecraft materials” o NASA-STD-5003, “ Fracture Control Requirements for Payloads Using the Space Shuttle” o MIL-STD-899, “Dissimilar Metals” o MIL-HDBK-6870, “ Metallic Materials and Elements for Aerospace Vehicle Structures”		
	2.3 MTO Project Documents		
	o JPLD-26405, “Mars Telecom Orbiter Preliminary Environmental Requirement Document” o JPL D-XXXXX, “ Project Configuration Management Plan” o o JPL D-XXXXX, “ Project Risk Management Plan”		
	3.0 Design, Verification, Process and Safety Requirements		
1.	Requirement : The requirements specified herein apply to all hardware	JPL D-15032,	

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	developers who shall extend these requirements to their subcontractors and suppliers through appropriate contractual documentation. Any deviation from these requirements must be waived in accordance with the applicable procedure for Category A and Category B Waivers. No requirement shall be waived without JPL approval.	"Category A Waiver Request/Approval " And JPL D-53052, "Category B Waiver Request/Approval"	
2.	Requirement. Each organization providing flight hardware shall create specific discipline assurance implementation plan(s) that will define in more detail the assurance programs to be employed at their respective organizations during the flight equipment development process. These implementation plans shall respond to the requirements specified in this document, and shall be submitted to JPL Mission Assurance for review and approval.		
	3.1 Reliability		
	Assurance of MTO reliability for required on-orbit operational period shall be achieved through the implementation of the integrated program described above in Section 1 and high reliability design and development requirements/ practices identified below. These include: (a) Successful completion of a comprehensive test program involving large margins over the expected environment and full compliance with imposed requirements (b) Verification of design robustness for end of life conditions detailed in a complete set of reliability analyses, such as worst case and parts stress analysis (c) Assurance of fault tolerance and protective measures, verified by Failure Modes and Effect Analyses (FMEA) s and/or Fault Tree		

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	Analyses (FTAs) (d) Application of high reliability standards for design, fabrication, inspection and test (e) Selection of Class S/ Level 1 electronic components and flight proven materials and processes (f) Extensive burn-in and operational testing of electronic assemblies.		
	3.1.1 Lifetime		
3.	Requirement. MTO hardware shall be designed to meet an 11-year mission (1 year cruise and 10 years on-orbit). During this 11-year period, the instrument shall meet all functional, performance and operational requirements under the environment specified in the Project Environmental Require ments Document	MTO JPL D-26405, "Mars Telecom Orbiter Preliminary Environmental Requirements Document"	
4.	Requirement. MTO hardware shall be designed to meet 60 months of powered pre-launch ground operations. This is in addition to the mission life for a total design life of 16 years.		No additional ground storage requirements will be added to the 60 months of powered pre-launch ground operations, as this requirement is already considered worst case.
5.	Requirement. Flight hardware shall be designed to operate over three times the expected mechanical cycles,three times the expected electrical power on/off cycles, and three times the expected number of thermal cycles. Total cycle number is the sum of cycles during assembly, integration testing & flight operations.		
6.	Requirement. Hardware not meeting the lifetime margins shall be classified as limited life hardware and will be identified along with the mitigation approach and method(s) for tracking usage.		
	3.1.2 Success-Critical Single Failure Point (SFP)		
	Requirement. Success critical SPFs are not permitted without formal		

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7.	Project level waiver, which requires justification based on risk analysis and measures implemented to minimize risk. All system level SPFs shall be identified and documented in a SPF list. No safety critical single point failures are allowed. Project shall maintain a mission SPF exemption list.		
8.	Requirement. Success-Critical Single Failure Points shall require a waiver. The waiver shall include: (a) Rationale for the acceptance (b) Risk impact on the mission (c) Mitigation approach		
	3.1.3 Operating Hours		
9.	Requirement. All flight hardware (flight hardware includes flight units, all spares that may be used as flight units, and both the A and the B redundant flight hardware) shall have accumulated a minimum of 300 hours of operating time prior to delivery for integration onto the spacecraft, with the last 100 hours to be failure-free.		This requirement can be satisfied by: (a) operating the hardware at ambient temperature, (b) during environmental test or (c) sum of operating time at (a) and (b).
10.	Requirement.. Prior to launch, all flight hardware shall have a minimum of 1000 hours of operating time for single-string electronic assemblies, or shall have a minimum of 500 hours operating time, with a goal of 1000 hours, for each side of block redundant electronic assemblies.	Design Principles	.
11.	Requirement. The last 100 hours of pre-launch operating time shall be failure-free.		
12.	Requirement. Both side A and side B of the redundant hardware shall meet operating hour requirements listed above, ID numbers (8), (9), and (10).		
13.	Requirement. Flight Spare hardware shall meet Operating hours requirements listed above, ID numbers (8), (9), and (10).		(a) This requirement applies to assemblies and not parts.

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14.	Requirement. All heaters used for MTO shall meet the 168 hours of operation as specified in paragraph 4.7.2 of NASA GSFC Specification S-311-P-079.	NASA GSFC Specification S-311-P-079, " Procurement Specification for Thermofoil Heaters"	
	3.1.4 Design/Reliability Analyses		
15.	Requirement: The MTO design robustness will be assessed through the use of the following analyses which shall utilize the methodology described in JPL D-5703 or PEM and MAM approved methodologies: (a) Failure Modes, Effects, and Criticality Analysis (FMECA) (b) Sneak Circuit Analysis (c) Electro-Mechanical Fault Tree Analysis (d) Electrical Worst Case Analysis (WCA) and Power Supply Transient Analysis (e) Electrical/Electronic Parts Stress Analysis (PSA) (f) Single Event Effect Analysis (g) Structural Stress Analysis (h) Thermal Stress Analysis	JPL D-5703, " Reliability Analysis for Flight Hardware in Design"	
	3.1.4.1 Failure Modes Effect and Criticality Analysis (FMECA)		
16.	Requirement. The main objective of a FMECA is to identify SPFs and to verify that failures will not propagate and damage other hardware. FMECAs shall be performed and documented to analyze postulated failures and identify the potential resultant effects. FMECAs shall be performed on the Flight configurations and on any support equipment that interfaces to flight hardware.		
17.	Requirements. FMECAs shall, as a minimum: (a) Be performed at the functional block level.		

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	(b) Be performed at the slice and/or assembly level interfaces to the piece part level to verify that a failure in any slice and/or assembly interface circuit cannot propagate to and/or damage the interfacing circuit and/or damage hardware in another fault containment region. (c) Verify that failures in ground support or test equipment cannot propagate to and damage the hardware. (d) Verify that a failure in a redundant system element will be detected and the capability exists to switch to the redundant system element to continue operation. (e) Verify that a failure in a non-critical circuit (e.g., telemetry, current monitoring, test interfaces not used in flight) will not affect the performance of a critical function. (f) Consider all operational modes (g) Identify Success-Critical Single Point Failures for which a waiver is required. .		
	3.1.4.2 Sneak Path Analysis		
18.	(b) Requirement. Subsystem interface circuits shall be analyzed to determine if sneak paths exist with powered and un-powered circuits. If sneak paths do exist, there must be assurance that they will not affect the function of the circuits involved nor cause overstress to any parts.		
	3.1.4. 3 Mechanical/ Electro-Mechanical Fault Tree Analysis		
19.	Requirement. A Fault Tree Analysis (FTA) shall be performed on mechanical and electromechanical devices. The FTA will address failure modes capable of occurring down to the lowest level piece part. This analysis shall be accomplished as follows: 1. Defining the top event failure mode, 2. Determine possible causes, considering effects based on the subsystem and system functional description.	JPL D-5703, " Reliability Analysis for Flight Hardware in Design	Mechanical FMECAs in lieu of FTAs is an acceptable method on a case-by-case basis. JPL reliability approval is needed for mechanical FMECA.

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	3. Determine an assessment of preventive measures and alternate modes of operation to avoid failure shall be performed. The corrective actions shall be documented as described in JPL D-5703. From the results of these analyses, engineering decisions can be made by the cognizant design organization that indicate whether or not additional analysis, testing, inspection, or other steps should be taken to increase the reliability of the assembly. These decisions shall be reported at the design reviews subsequent to completing the analysis.		
	3.1.4.4 Electrical Worst Case Analysis (WCA) and Power Supply Transient Analysis		
20.	Requirement. A WCA shall be performed and documented for all circuit designs. The analysis shall demonstrate that sufficient operating margins exist under all operating conditions and performance requirements. Analysis shall include the cumulative effects of the following: (a) Part case temperature obtained from thermal analysis (b) Piece part initial tolerance (c) Part aging for the operating life of the mission including ground test time (total of 16 years 11 years mission 5 years ground testing). (d) Radiation effects (TID) (e) Special factors such as shock, vibration, or vacuum where such conditions would contribute to variation in circuit parameters, voltage, frequency, and load variations shall also be included		If part case temperature is not available from thermal analysis, use 20°C plus base plate
21.	Requirement. The WCA shall: (a) Be an Extreme Value Analysis (EVA) or extreme value with temperature tracking, in that the value for each of the variable parameters shall be set to limits that will drive the output to a maximum (or minimum) and shall consider AC, DC, and transient condition effects on the circuit. Piece part parametric data obtained from testing will be incorporated into the WCA as appropriate. (b) Include the protective circuitry to ensure proper operation if a fault		

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	were to occur (c) Consider electrical noise on power lines, including ground differences, and interface signal lines. (d) Electrical noise on power lines, including ground differences, and interface signal lines shall be considered. Power supply turn on and turn off transients shall be included. (e) The documentation of the WCAs shall describe all identifiable deficiencies and performance restrictions.		
22.	Requirement. The radiation and temperature used in the analysis shall be: (a) Radiation: per JPL D-26405, Preliminary MTO ERD, (b) Temperature: thermal control surface of -35° C and 75° C or allowable flight temperature limits extended by –15° C and +20° C whichever is greater. (c) Temperature Rise: +15° C	JPL D-26405, "Mars Telecom Orbiter Preliminary Environmental Requirements Document"	If thermal analysis indicates a part temperature outside of the range used in the analysis, the WCA must be amended to take into account the thermal analysis predicted temperature.
23.	Requirement. Worst-case mechanical analyses shall be performed to ensure that worst-case mechanical tolerances and thermal environments cannot adversely affect the performance of mechanical hardware.		
	3.1.4.5 Electronic Parts Stress Analysis (PSA)		
24.	Requirement. PSA shall be performed to verify that the applied stress on each piece part does not exceed the derating values established in JPL D-8545 Rev D.	JPL D8545 Rev. D, "JPL Derating Guidelines"	
25.	Requirement. The voltages and temperatures used in the analysis shall be: (a) Voltage: Maximum and minimum bus voltage (b) Temperature: Thermal control surface of -35° C and 75° C or allowable flight temperature limits extended by –15° C and +20° C whichever is greater. (c) Temperature Rise: +20° C or the thermal analysis listed part temperature when they are available.		If thermal analysis indicates a part temperature outside of the range used in the analysis, the PSA must be amended to take into account the thermal analysis predicted temperature.
	3.1.4.6 Single Event Effects (SEE) Analysis		

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26.	Requirement. Circuit designs containing Single Event Effects (Single Event Upsets and Single Event Transients) sensitive electronic parts shall be analyzed to provide either an assembly upset rate or upset probability during mission critical time.		
27.	Requirement. Irreversible SEE shall not be permitted.		
28.	Requirement. Temporary loss of function or loss of data will be permitted provided: a. The loss does not compromise subsystem/system health. b. Full performance can be recovered. c. There is no time in the mission that the loss is mission critical. d. Normal operation and function will be restored via internal correction methods without ground intervention in the event of an SEU. e. Does not impact mission science requirements.		
29.	Requirement. Fault traceability will be provided in the telemetry stream to the greatest extent practical for all anomalies involving SEEs.		
	3.1.4.7 Structural Analysis		
30.	Requirement. A structural stress analysis shall be performed on mechanical and electromechanical (e.g., actuators) subsystems/assemblies at the slice and subsystem level. The analysis shall address the effects to be experienced by the structure due to the dynamic environment (i.e., acceleration, shock, vibration, and acoustic noise), including worst-case estimates for design environmental conditions.		
	3.1.4.8 Thermal Analysis		
31.	Requirement. Thermal analysis shall be performed and documented. The analysis shall: (a) Address the effect of the thermal environment, including worst case estimate (b) The analysis shall address material properties and the effect of thermal cycling on solder joints, conformal coating, and other critical materials.		

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	(c) Generate piece part temperature and junction temperature.		
	3.1.5 Problem/Failure Reporting (P/FR)		
32.	Requirement. A closed-loop Failure Reporting, Analysis, and Corrective Action System shall be implemented to assure anomalies are thoroughly investigated, properly documented and that corrective actions are implemented in a timely fashion. Developmental Problem/Failure Reports (DP/FR) shall be utilized for reportable incidents involving the items listed below. DP/FRs may also be used during breadboard activities. (a) Non-flight-like Hardware (b) Developmental Flight Software (c) Support equipment (hardware and software) (d) Test software Formal Problem/ Failure Reports (P/FR) shall be used for all reportable incidents involving the following : (a) Flight-like and Flight (FLT) hardware (e.g. Qualification Engineering Model (QEM),Flight (FLT) hardware, life qualification hardware, or any other flight-like hardware. (b) Flight Software (c) Support equipment (hardware and software) (d) Facility equipment (hardware and software) (e) Safety violations	JPL D 8091,” Standard for Anomaly Resolution”	
33.	Requirement. Developmental Problem/Failure Reports (DP/FR) starting point shall be : (a) Non-flight-like Hardware to begin at first application of power of each non-flight-like assembly. (b) Developmental Flight Software to begin at software integration and testing. (c) Support equipment hardware and software (including test and facility equipment) during GSE acceptance testing.		

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	(d) Test software to begin at testing of hardware delivered by Integration and Test. (e) Support equipment hardware and software (including test and facility equipment) during GSE acceptance testing. . Formal failure reporting, using a JPL Problem/Failure Report form shall begin with: (a) Flight-like and Flight Hardware to begin at first application of power. (b) Mechanical or electromechanical, the first functional /performance test of the hardware, qualification model, flight model or protoflight model (c) Flight Software to begin at acceptance testing and all subsequent tests or when testing with flight and/or flight-like hardware. (d) Support equipment hardware and software (including test and facility equipment) in acceptance testing or while testing the items in (a) and/or (b) above. (e) Facility equipment when used with items in (a) or (b) above. (f) Hardware damage or safety violations to flight-like or flight hardware, facilities, or personnel (g) Test software while testing the items listed in (a) or (b) above.		
34.	Requirement. P/FR shall be written for any of the following reportable incidents: (a) (a) All hardware failure, damage, problems, malfunctions, anomalies, nonstandard or unexpected results, and incidents of performance outside specification limits; also incidents of anomalous dynamic performance such as glitches, drifts, transients, stepping, oscillation, etc within specification. (b) All software and procedure problems, errors, ambiguities encountered with software while utilized with MTO hardware or while being checked in preparation for operation with MTO hardware or while in the workstation environment.		

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	(c) All Support equipment, test equipment, or test facilities problem, failure, and anomalous performance, including procedure and operator actions, while being utilized in conjunction with MTO hardware or while being checked in preparation for operation with MTO hardware. (d) All incidents involving actual or potential damage to hardware, software, or injury to personnel from testing, handling, shipping, or storage.		
35.	Requirements. The individual in charge of the activity, the MTO hardware, software, test equipment, or support equipment at the time when a reportable incident occurs shall have the primary responsibility to originate the P/FR; however any individual observing a reportable incident is responsible to originate a P/FR.		
36.	Requirements. All problem/failure incidents shall be entered electronically into the JPL Unified Problem Reporting System (UPRS).		
37.	Requirement: Each problem/failure report shall be assigned two factored assessment, in accordance with JPL D-8091 “Anomaly Resolution”, which leads to a statement of risk as follows: “Failure Effect Rating”, the first factor, is an assessment of the consequence or impact of the problem or failure if it had occurred in flight. Redundancy shall not be considered in making this assessment. The assessment shall be 1,2,or 3 based on the criteria listed below: Rating 1: Negligible effect on mission performance and system safety. (a) No appreciable change in functional capability. (b) Minor degradation of engineering or science capability. (c) Support equipment or test equipment problem/failure. (d) SE, TE, or operator induced failure. (e) Workmanship failures found at initial test opportunity. (f) Causes negligible operational difficulties or constraints. (g) Negligible or no reduction in lifetime. (h) Cannot occur in flight. (i) Minor safety violation. Rating 2: Significant effect on mission performance or system safety.	JPL D-8091 “Anomaly Resolution”,	

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	(a) Appreciable change/degradation in functional capability. (b) Appreciable degradation of engineering or science capability. (c) Causes significant operational difficulties or constraints. (d) Significant reduction in lifetime. (e) Significant safety violation. Rating 3: Major or catastrophic effect on mission performance or system safety. (a) Major change/degradation in functional capability. (b) Major degradation of engineering or science capability. (c) Causes major operational difficulties or constraints. (d) Major reduction in lifetime. (e) Major safety violation. "Failure Cause /Corrective Action Rating", the second factor is an assessment of the certainty that the exact failure cause has been determined and that the corrective action will eliminate any known possibility of recurrence of the problem/failure in flight. The assessment shall be 1, 2, 3, or 4 based on the criteria listed below. Rating 1: Known Cause/Certainty in corrective action. Analysis, corrective action and verification of correction are considered to have determined the cause and have defined an effective corrective action that has been implemented and verified by test or other demonstration. No known possibility of recurrence in flight. Rating 2: Unknown Cause/Certainty in corrective action. The cause could not be completely determined, but an effective corrective action has been implemented and verified by test or other demonstration; or the problem/failure (observed incident) could not be repeated in tests or checkouts. No known possibility of recurrence in flight. Rating 3: Known Cause/Uncertainty in corrective action. Analysis, corrective action and verification of correction are considered to		

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	have determined the cause, but effective corrective action has not been implemented and verified by test or other demonstration. Some possibility of recurrence in flight. Rating 4: Unknown Cause/Uncertainty in corrective action. The cause could not be completely determined and no effective corrective action has been implemented and verified by test or other demonstration. Some possibility of recurrence in flight.		
38.	Requirement. Analyses of the DP/FR or P/FR will be conducted to the extent necessary to define the problem, determine the failure mechanism, identify whether parts may have been overstressed as a result of the failure, address the effect of the incident on associated elements of the subsystem and the system (including near and long-term effects on desired functional performance), and determine the necessary corrective action. The proposed corrective action will be analyzed to ensure that the implementation will address both the problem and any interactions with other elements of the subsystem and the system.		
39.	Requirement. When corrective action is implemented, all documents defining changes in design configuration or document revisions shall be processed in accordance with configuration control requirements and referenced on the DP/FR or P/FR prior to closeout review and approval. Verification of corrective action shall involve appropriate analyses, breadboard or prototype tests, rerun of qualification, proto-flight or acceptance tests, regression testing, or the completion of special tests to ensure that correction has been accomplished. After completion of the corrective action, the item must again be subjected to the conditions under which the problem/failure occurred and must perform successfully under those conditions.		
40.	Requirement. All DP/FRs and P/FRs having a Failure Effect Rating of 2 or 3 coupled with a Failure Cause/Corrective Action rating of 3 or 4 are defined as “Red Flag” DP/FRs and P/FRs. (a) Each DP/FR, which is a potential Red Flag, or a DP/FR with impact on		

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	flight hardware or software shall be converted to a P/FR and be subjected to the P/FR review/approval process. (b) Each Red Flag P/FR must include a Red Flag Summary regarding the rationale for accepting the residual risk. (c) The JPL Project Manager and the Contractor Project Manager (if applicable) shall review, approve and sign Red Flag P/FR closures to acknowledge understanding and acceptance of the defined residual mission risk. (d) All Red Flag P/FRs shall be discussed at subsequent formal reviews.		
41.	Requirement. Each DP/FR and P/FR shall be reviewed by System Safety to determine if there is any potential adverse effect on personnel safety or hardware safety associated with the problem/failure. It is the responsibility of each DP/FR and P/FR reviewer to determine that the assigned safety ratings are appropriate. All DP/FRs and P/FRs with a hardware or personnel safety issue shall have a safety risk assessment made by the JPL Systems Safety office and shall be signed by the JPL Systems Safety Engineer and the Contractor Safety Engineer (if applicable).		
42.	Requirement: All reportable incidents: (a) Shall be documented within one working day of incident/ observation and be assigned a preliminary risk rating within ten days of occurrence of the incident. (b) For contractor generated P/FRs 1. Initial contactor notification and coordination with JPL shall be within one working day of the incident. 2. Initial contractor submittal shall consist of JPL form with the origination section completed or a copy of the Contractor's report as released with initial reporting data sections completed. The form shall be submitted to JPL and/or entered into the JPL UPRS within two working days of the incident. The UPRS will then electronically inform the Contract Technical Manager and JPL Cognizant Engineer that the report is in the JPL UPRS automated system. The Monthly Technical Progress Reports		P/FR Form: JPL P/FR Form 1846 or equivalent as approved by JPL

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	will include a summary of DP/FRs and P/FRs generated during the reporting period. 3. Interim submittals to JPL will consist of updated releases of the Contractor's report and copies of referenced supplemental data and documents. Submittals will be sent to the JPL UPRS. 4. Final Submittal shall consist of the Contractor's signed P/FR with copies of referenced supplemental data/documents not previously submitted. Prior to submittal of a Contractor signed P/FR to JPL, the verification analysis and corrective action must be reviewed and approved by both contractors' Project Engineer and the Contractor's Product Assurance Manager. Also, in the case of Red Flag P/FRs, the Contractor's Project Manager must review and approve the P/FR. 5. The P/FR shall not be considered closed by the contractor until it has been approved by the JPL cognizant engineer, PEM, Reliability Engineer, Mission Assurance Manager, and in the case of red flag P/FRs, the JPL Project Manager		
43.	Requirement. Each P/FR shall be subjected to a review, approval, and closure process as follows: (a) The cognizant engineer and the reliability engineer shall perform a preliminary review of each P/FR. Each P/FR shall be assessed and rated for safety concerns, assigned a cause code, and a cause/corrective action rating (b) Electronic parts and environmental test technical specialist shall review and approve P/FRs related to their disciplines for closure (c) Closure of a P/FR requires that all signatures are on P/FR in following order: a. Cognizant Engineer and Project Element Manager (PEM) for all P/FRs b. Hardware and Software Reliability Engineers for all P/FRs c. Flight System Engineer for P/FRs which: i. Results in Engineering Change Request to hardware or software		

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	ii. Results in waiver to level 4 or higher functional requirements iii. Have an unknown cause iv. Have a cause /corrective action rating of 3 or 4 d. Safety Engineer shall review all P/FRs to assess for hardware or personnel safety e. Project Mission Assurance manager for all P/FRs f. Flight System Manager and Project Engineer for P/FRs which result in an ECR or waiver to a level 2.5 or higher requirement. g. Project Manager and Flight System Manager for Red Flag P/FRs (d) Closure of contractor P/FRs requires JPL Cognizant Engineer, PEM, Reliability, and Mission Assurance Manager signature, and in the case of Red Flag P/PRs, the JPL Project Manager. (e) Contractor generated P/FR risk rated as red flag requires contractor project manager and product assurance manager approval and signature		
44.	Requirement. Each DP/FR will be subjected to the same process as the P/FRs, however, closure of a DP/FR only requires the Cognizant Engineer's and PEM's signature.		
45.	Requirement. Each DP/FR and P/FR shall be reviewed by System Safety to determine if there is any potential adverse effect on personnel safety or hardware safety associated with the problem/failure. It is the responsibility of each DP/FR and P/FR reviewer to determine that the assigned safety ratings are appropriate. All DP/FRs and P/FRs with a hardware or personnel safety issue shall have a safety risk assessment made by the JPL Systems Safety office and shall be signed by the JPL Systems Safety Engineer and the Contractor Safety Engineer (if applicable).		
46.	Requirement. Each contractor organization external to JPL that is providing MTO hardware and/or software shall: (a) Establish a system for controlling and monitoring the status of P/FRs		

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	generated under its cognizance, as approved by the JPL Reliability Engineer and Mission Assurance Manager. (b) Meet the requirements of this document (c) Impose these requirements down to the subcontractors and suppliers.		
	3.2 EEE Parts		
	3.2.1 Purpose		
47.	Requirement. Every Electrical, Electronic and Electromechanical (EEE) part intended for use in space flight shall be reviewed and approved for compatibility with the intended space environment and mission life.		
48.	Requirement. All parts shall satisfy the MTO environmental requirements as specified in the Project ERD.	JPL D-26405, “Mars Telecom Orbiter Preliminary Environmental Requirements Document”	
49.	Requirement. All parts lists shall be reviewed and approved by the appropriate JPL parts specialist.		
50.	Requirement. Level 1 / Class S parts shall be used where available and within cost and schedule constraints.		
	3.2.1.1 Standard Parts		
51.	Requirement. For the MTO, standard parts are defined as those that meet or exceed the following reliability standards: (a) NPSL (NASA Parts Selection List) Level 1 (with additional requirements as specified below in (b)-(e)) (b) MIL-PRF-38534 Class K QML Source, Product Conformance Inspection required on flight lot (minimum 3 pieces), provided CI/PI has not been performed within 1-year of procured lot date code on same part type		

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	(c) MIL-PRF-38535 Class V, QML-38535 (d) MIL-PRF-19500 Class JANS, QPL-19500 (e) Military Established Reliability (ER) passive devices, Failure Rate Level S or R. Capacitors procured to Weibull distributions shall be Weibull Level C or D. (f) MIL-PRF-38535 Class Q, QML-38535 if life test within 1-year of procured lot date code on same part type. Upgrade shall be required consisting of 100% PIND for cavity devices, 100% X-ray, and sample DPA (including RGA for cavity devices). Optimization issues will be addressed by JPL Parts Engineering in the parts list review. (g) MIL-PRF-19500 Class JANTXV, QPL-19500 with upgrade: Transistors – 100% X-ray, 100% PIND for cavity devices, sample DPA (including RGA for cavity devices); Diodes –100% PIND for cavity devices, sample DPA; Optocouplers - 100% X-Ray; sample DPA (includes RGA for cavity devices); Photodiodes/LEDs - 100% PIND for cavity devices, 100% X-Ray; sample DPA (includes RGA for cavity devices).		
	3.2.1.2 Non- Standard Parts		
52.	Requirement. Parts not meeting the minimum quality and reliability criteria of standard parts in 3.2.1.1 shall be categorized as non-standard parts. All non-standard parts shall be upgraded/screened to the standards of 3.2.1.1 and as specified on individual NSPAR's (Non-Standard Part Approval Request) and approved by the JPL Parts Engineering and Radiation	JPL D-19426, "Plastic Encapsulated Microcircuits (PEM's) Reliability/ Usage Guidelines	Unique, custom parts (e.g., ASICs and Custom Hybrids) and commercial parts (COTS, PEM's, etc.) are considered non-

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	Specialists. Plastic parts shall be screened in accordance with JPL D-19426, or contractor equivalent.	for Space Applications”	standard parts and require a NSPAR.
	3.2.2 Application Specific Integrated circuit (ASIC) Requirements		
	3.2.2.1 Digital ASIC Test		
53.	Requirement. Digital logic circuitry in ASICs (including microprocessor, microcontroller and all custom designs) shall be tested to at least 95% stuck-at fault coverage as is defined by MIL-STD-883, Method 5012. In addition, each major functional element of the design shall be tested to at least 90% stuck-at fault coverage. Quiescent current (all vector Iddq method) tests shall be based on a set of vectors that will toggle 95% of the nodes. In addition, each major functional element of the design shall be tested to at least 90% node toggle coverage. Additional tests shall be conducted at room temperature and at maximum rated (hot and cold) temperature that include: 1) Operating speed (or maximum testable speed) functional test to verify all functions of the design and, 2) DC and AC parametric test vectors in compliance with the ASIC specification.		
	3.2.2.2 Mixed Signal ASIC Test		
54.	Requirement. For Mixed-signal ASICs with large monolithic digital elements that amount to more than 10% of the design and more than 500 gates, these digital elements shall meet the requirements in paragraph 3.2.2.1. For Mixed-signal ASICs which are predominantly analog circuits with intermingled flip-flops, registers and counters that amount to less than 10% of the overall design complexity and less than 500 gates, these		

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	intermingled digital elements are exempt from the requirements in paragraph 2.4.1. Analog, digital, and mixed signal ASICs shall be modeled or simulated and compared with test data. Additional tests shall be conducted at room temperature and at maximum rated (hot and cold) temperature that include: 1) Operating speed (or maximum testable speed) functional test to verify all functions of the design and, 2) DC and AC parametric test vectors in compliance with the ASIC specification.		
	3.2.3 Custom Hybrid, MCM and HDI Microcircuits		
55.	Requirement. Custom hybrid devices designed and fabricated by non-QML sources shall be in conformance with requirements of Class K reliability level of MIL-PRF-38534.	MIL-PRF-38534	
56.	Requirement. Custom hybrid QML sources shall be in conformance with Class K reliability level of MIL-PRF-38534.	MIL-PRF-38534	
57.	Requirement. Document review and pre-cap inspection shall be performed by JPL for all hybrids prior to seal.		
58.	Requirement. All substrates for use in custom hybrids or MCM, shall be subjected to MIL-PRF-38534 substrate element evaluation.	MIL-PRF-38534	
59.	Requirement. All Low Temperature Co-fired ceramic (LTCC) substrates shall be qualified and screened. LTCC qualification and screening test program shall be approved by JPL.		
	3.2.4 Post-Programming Burn-In for Programmable Devices		
60.	Requirement. For “one time” programmable devices (a) A post programming 96 hour burn in test at 125° C + 0°/-3° shall be performed. (b) Post Burn in DC parametric tests at temperatures of -55°, 25° and 125° C shall be performed. (c) Pre and post burn in functional tests shall be performed. (d) For "one time" programmable devices (i.e. PROMs and FPGAs) any		

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	device that fails to program correctly on the first attempt shall be rejected without exception. (e) After programming DC parametric and at-speed functional testing shall be performed at three temperatures: at room temperature and maximum specified hot and cold temperatures. (f) The at-speed functional tests shall verify all functions, operating modes, fault responses (including initialization and resets) and the specified performance of the design.		
	3.2.5 Destructive Physical Analysis (DPA) and Residual Gas Analysis (RGA)		
61.	Requirement. DPAs and RGAs shall be performed per the requirements of SSQ25000 for each manufacturing lot date code of Grade 2 and lower EEE Parts. Ceramic capacitors rated at < 100V and used in < 10V applications shall be subjected to DPA. The dielectric thickness shall be verified to be a minimum of 0.8 mils.	SSQ25000	
	3.2.6 Particle Impact Noise Detection (PIND)		
62.	Requirement. All cavity devices shall require PIND testing in accordance with MIL-STD-883, Method 2020, Condition “A”. Parts being PIND tested will be subject to one pass only.	MIL-STD-883, Method 2020, Condition “A”	
	3.2.7 Radiographic Inspection		
63.	Radiographic inspection shall be in accordance with the applicable military specification (i.e. MIL-PRF-38534 for hybrid microcircuits, MIL-STD-750 for semiconductor devices, etc).		
	3.2.8 Solid Tantalum Style Capacitor Additional Screening		
64.	Requirement. All solid tantalum capacitors shall be subjected to 100% surge current testing. CWR type capacitors shall be tested in accordance with test option B of MIL-PRF-55365, CSS type capacitors shall be tested in accordance with the appropriate slash sheet of MIL-C-39003.	MIL-PRF-55365	
	3.2.9 Radiation		

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65.	Requirement. All parts shall be evaluated for radiation Total Ionizing Dose (TID), Displacement Damage (DD) and Single Event Effect (SEE) sensitivity.	JPL D-26405, "Mars Telecom Orbiter Preliminary Environmental Requirements Document"	
66.	Requirement. All candidate radiation sensitive parts: (a) Shall undergo characterization testing and /or lot acceptance testing or (b) Shall demonstrate by analysis based on test data to be compatible with the MTO radiation levels.		
67.	Requirement. Device types that are not fabricated on a radiation hardened process shall be subjected to Radiation Lot Acceptance Testing (RLAT)		
68.	Requirement. All linear bipolar and BiCMOS ICs shall be evaluated for susceptibility to Enhanced Low Dose Rate Sensitivity (ELDRS). JPL shall review and approve these parts for use.		
69.	Requirement. ELDRS test plan and procedure shall be approved by JPL.		
70.	Requirement. All flight parts shall operate within post-irradiation specification limits following exposure to twice the expected total dose environment (i.e., Radiation Design Factor (RDF) of 2) specified in JPL D-26405, "Mars Telecom Orbiter Preliminary Environmental Requirements Document"	JPL D-26405, "Mars Telecom Orbiter Preliminary Environmental Requirements Document"	
71.	Requirement. All devices shall be evaluated for susceptibility to Displacement Damage (DD). All devices shall operate within specification limits following exposure to twice the expected environment (i.e., RDF of 2) specified in JPL D-26405, "Mars Telecom Orbiter Preliminary Environmental Requirements Document"	JPL D-26405, "Mars Telecom Orbiter Preliminary Environmental Requirements Document"	
72.	Requirement. All microcircuits containing bistable elements (e.g. flip-flops, counters, RAMs, microprocessors, etc.) shall be characterized so that an upset rate calculation can be performed. All parts shall be tested to a		

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	fluence of 10^7 ions/cm². The requirements for parts Single Event Upset (SEU) acceptability are: (a) No upsets observed during SEU testing to an LET of 75 MeV-cm^2/mg, or (b) Verification of device bit error rate of 10^{-10} per day or better in the galactic cosmic ray environment, or (c) Calculation of a device's upset rate shall be equal to or less than the required circuit upset rate as determined by circuit SEU analysis.		
73.	Requirement. All devices (including those with epitaxial layers) shall be subject to latch-up evaluation. Each devices shall meet the following requirement: (a) No latch up to an LET of 75 MeV-cm^2 /mg or (b) No latchup to an LET of 75 MeV-cm^2/mg, or (c)Verification that the device latchup probability in the mission environment be < 10^{-4} /device-year for parts that exhibit latchup between 35 Mev-cm^2/mg and 75 MeV-cm^2/mg Devices not meeting above requirements shall be tested to a fluence of 10^7 ions/cm^2. Test plan and procedure shall be reviewed and approved by JPL radiation specialist prior to testing.		A waiver is required for LET sensitive devices used in the circuits with latch up protection circuitry.
74.	Requirement. All power MOSFETs operated in the off-mode shall be evaluated for, single event gate rupture (SEGR) at the worst-case application V_{GS}. The survival voltage (V_{DS}) shall be based on exposure to a minimum fluence of 10^6 ions/cm² of an ion with a minimum LET of 37 MeV-cm^2/mg and with a range greater than 100 microns. The application voltage shall be derated to 75% of the established survival voltage.		
75.	Requirement. All power transistors operated in the off-mode shall be evaluated for, single event burnout (SEB) at the worst-case application V_{BE} (for bipolar devices) or V_{GS} (for MOS devices). The survival voltage (V_{CE} or V_{DS}) shall be based on exposure to a minimum fluence of 10^6 ions/cm² of an ion with a minimum LET of 37 MeV-cm^2/mg and with a range greater than 100 microns. Testing shall be performed with normal beam incidence and		

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	at room ambient temperature. Test requirements for single event burnout shall be identical to those for SEGR except that the drain current (or collector current for bipolar transistor) shall be measured to determine if burnout occurs. The application voltage shall be derated to 75% of the established survival voltage.		
	3.2.10 Waiver and Alerts Requirements		
	3.2.10.1 Waivers		
76.	Requirement. A waiver shall be submitted by the H/W supplying organization and approved by JPL Parts Engineering for parts not meeting the parts requirements specified herein, or required in a JPL-approved NSPAR.		
	3.2.10.2 NASA Advisories and Government Industry Data Exchange Program (GIDEP) Alerts		
77.	Requirement. All hardware-delivering design agencies, both internal and external to JPL, shall assure the implementation of a system to review NASA Advisories and GIDEP Alerts, take appropriate action, and notify their respective Alert coordinators of significant parts problems that may warrant issuance of new Alerts. This activity shall continue throughout the Project's lifecycle. Design agencies which do not presently receive Alerts directly should request distribution from the Defense Supply Center Columbus (DSCC), GIDEP Operations Center or the JPL Alert Coordinator. The design agency is responsible for reviewing all Alerts, and for immediately reporting corrective action for applicable Alerts (i.e. for parts used in the hardware) to the project and appropriate Alert Coordinator. The design agency will present a review matrix of all Advisories and Alerts at the CDR, and at the Pre-Ship Review, that lists all of the Alerts which are pertinent to the parts used in the flight design, the possible impact should the part fail, and the actions proposed and those taken. It is the		

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	responsibility of the design agency to avoid the use of defective parts in flight equipment.		
	3.3 Quality Assurance		
	3.3.1 Quality Management System		
78.	Requirement. All prime contractors and sub-tier contractors shall be ISO 9001 certified or have a JPL QA approved equivalent Quality Management System.		
79.	Requirement. Procurement procedures require acquisition of products and services from sources on the *Approved Suppliers List*	JPL Flight Project Practices (FPP), Rev. 5: Paragraph 5.14.3	
80.	Requirement. Procurement Quality Assurance, in conjunction with the Project Quality Assurance Engineer, shall Survey/Audit the Contractor's Quality System..		
81.	Requirement. Contractors shall flow down JPL requirements to sub-tier vendors and ensure that sub-tier vendors supporting the MTO Project produce hardware and services that meet JPL requirements.		
82.	Requirement. Contractors shall qualify their sub-tiers prior to contract award and for the monitoring and quality of parts produced by sub-tier vendors. Upon request, the contractor shall make available to JPL QA system the survey records and the records of performance.		
83.	Requirement. Contractor shall designate at least one person as the manager or lead dedicated to the MTO Project, representing the contractor's Quality Assurance (QA) organization.		
84.	Requirement. Contractors shall provide: (a) JPL QA representative unescorted access to appropriate areas of the facility, a desk, and computer for resident assignment; (b) Notification of meetings, reviews, testing, test set-ups, inspection		

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	points, and other activities that require JPL involvement shall be given to the JPL representative in advance; (c) Minimum of three working days notice to JPL QA for itinerant source inspections.		
85.	Requirement. The Contractor shall submit a Quality Assurance Plan which describes how the listed QA requirements will be met.	JPL Flight Project Practices (FPP), Rev. 5: Paragraph 7.3.6	
	3.3.2 Critical Processes		
86.	Requirement. Contractors shall demonstrate capabilities for critical processes that affect the quality of the parts or hardware being built including, but not limited to the following : Workmanship Standards Fabrication, Assembly, and Test Planning Material Storage and Control Inspection Planning Procurement Support Hardware Handling, Storage, and Shipment Environmental Testing Subsystem Integration and Test, or Assembly, Test, and Launch Operations (ATLO), as appropriate	JPL D-8208, "Spacecraft Design and fabrication Requirements for Electronic Packaging and cabling"	(1) Contractors' capabilities can be demonstrated using various methods including metrics and process control charts. (2) Critical processes include but are not limited to the following: (a) Plating, (b) Anodizing, (c) Heat treating, (d) Welding, (e) Soldering, (f) Polymeric applications, (g) Cleaning, (h) Die attachment, (i) Wire bonding, (j) Magnetic Particle inspection, (k) Radiographic inspection, (l) Ultrasonic inspection, (m) Liquid penetrant inspection
87.	Requirement. All processes used such as Electro-Static Discharge control plan, workmanship standards; contamination control shall meet or exceed	(1)JPL D1348, " Standard for Electrostatic	

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	NASA or JPL requirements.	Discharge Controls" (2) JPL D-8208, "Spacecraft Design and Fabrication Requirements for Electronic Packaging and Cabling"	
88.	Requirement. All hardware containing electronic circuitry shall be protected from electrostatic discharge (ESD) damage.	(1)JPL FPP, paragraph 6.12.5.4 (2) JPL D-1348, " Standard for Electrostatic Discharge Controls"	
	3.3.3 Quality Records and Controlled Documents		
89.	Requirement. Hardware provider shall: (a) Retain quality Records and furnish them to MTO project (b) Maintain traceability on all JPL hardware designed as flight, flight spare, engineering model, ground support equipment and other critical equipment that interfaces with flight hardware.		
90.	Requirement. Hardware fabricated and/or assembled at JPL or procured shall include a data package sufficient enough to validate a pedigree as flight worthy and to support a failure investigation, if necessary.		Requirement for EIDP and As-Built-Data will be defined in the Purchase Order or Contract Statement of Work (SOW).
	3.3.4 Training		
91.	Requirement. Hardware provider shall:	NASA 8739.2 and	JPL review and

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	(a) Provide adequate training and certification to personnel to insure they are qualified to perform critical processes, (b) Ensure that sub-tier contractor personnel are appropriately qualified and certified as well.	.3, or contractor equivalent document.	approved training courses.
92.	Requirement. Quality Assurance shall verify that all certifications are current and valid.		
93.	Requirement. All personnel involved in handling or testing of flight hardware are certified to standards approved by the responsible QA organization.	JPL Flight Project Practices (FPP), Rev. 5: Paragraph 7.3.4	
	3.3.5 Non-Conformance Reporting		
94.	Requirement. Hardware provider shall have a closed loop reporting system for the handling of non-conformances with a means to measure effectiveness of the corrective action.		
95.	Requirement. Non-conformances that impact the performance, function, or fit up of the part or any that require non-standard critical repairs shall be elevated to the Material Review Board level, requiring JPL MTO Project visibility and approval.		
	3.3.6 Handling, Packaging, Shipping, and Storage Control		
96.	Requirement. Hardware provider shall have documented and approved processes for handling, packaging, shipping, and storage of critical hardware.		
97.	Requirement. Non-conforming hardware shall be kept in areas only designated for non-conforming hardware with precautions made to prevent the co-mingling of these parts with other acceptable hardware.		
98.	Requirement. All EEE parts and materials procured for MTO shall be segregated and stored in a dedicated, controlled storage area.		
99.	Requirement. Hardware not under the cognizant engineer's or contract technical manager's(CTM) immediate control shall be housed in an area certified by the responsible quality assurance(QA) organization, or in a controlled access facility such as for spacecraft assembly or launch processing.	JPL Flight Project Practices (FPP), Rev. 5: Paragraph 6.12.2	

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100.	Requirement. Procedures governing the moving and storing of critical hardware within a given facility shall be approved by the responsible QA organization.	JPL Flight Project Practices (FPP), Rev. 5: Paragraph 6.12.4	
101.	Requirement. QA, Safety and other Transportation Surveys shall be initiated to ensure the safe movement of all flight hardware.	JPL Flight Project Practices (FPP), Rev. 5: Paragraph 6.12.5.1	
	3.3.7 Inspection		
102.	Requirement. Quality Assurance personnel perform receiving and shipping inspections on all critical hardware whenever the hardware enters or leaves any facility(e.g.,JPL or contractor facility). Critical hardware includes all flight hardware and any GSE that interfaces directly with flight hardware.	JPL Flight Project Practices (FPP), Rev. 5: Paragraph 7.3.1	
103.	Requirement. JPL QA resident and/or itinerant support is provided at Contractors and critical suppliers of flight hardware.		
104.	Requirement. Final inspection of flight hardware is performed to formally released documents.	JPL Flight Project Practices (FPP), Rev. 5: Paragraph 7.3.2	
105.	Requirement. Projects define mandatory inspections for critical hardware(e.g., in-process and final) at JPL, subcontractors and suppliers.	JPL Flight Project Practices (FPP), Rev. 5: Paragraph 7.3.3	
	3.3.8 Fabrication, Assembly and Testing		
106.	Requirement. All facilities intended for processing, operations or testing flight hardware shall undergo a combined audit by the responsible QA, Safety and technical organizations to ensure their suitability for the intended efforts. The Project Systems Safety Engineer ensures that potential hazards to hardware or personnel safety are corrected prior to the start of	JPL Flight Project Practices (FPP), Rev. 5: Paragraph 6.12.3	

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	the effort.		
107.	Requirement. QA oversees and monitors all environmental testing of flight hardware as a unit, or as an element of a larger assembly, according to written, approved procedures, and identifies and measures protection related to the safety of the unit and personnel.	JPL Flight Project Practices (FPP), Rev. 5: Paragraph 6.12.6	
	3.3.9 Assembly, Test, and Launch Operation Support		
108.	Requirement. JPL QA shall provide the necessary support, as determined by Mission Assurance Management, to ensure correct and safe integration of hardware deliverables. QA activities may include, but not be limited to: (a) Review and certification of transportation vehicles (b) Post-transportation inspection (c) Surveillance and monitoring to assure compliance to Spacecraft processing and testing procedures (d) Performing and documenting inspections that are necessary (e) Verification of completion of all required hardware (f) Verification of compliance to procedures and requirements regarding Spacecraft/Payload in preparation for Launch Vehicle integration (g) Participation in Launch Vehicle Integration Readiness Reviews (h) Ensure Project Handling Constraints are clearly identified and complied with in integration procedures (i) Monitoring and ensuring Spacecraft/Payload contamination control procedures are followed		
	3.3.10 Government Furnished Equipment and Materials(GFE)		
109.	(a) Requirement. Government-furnished equipment and materials shall be controlled in accordance with JPL's ISO 9001 institutional policies and procedures. Contractors responsible for JPL government-furnished property shall control it in accordance with the applicable contract Statement-of-Work requirements and per appropriate in-house GFE procedures. JPL QA shall assure appropriate handling and storage controls are in place at all contractors.		

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	3.3.11 Software (S/W) Quality Assurance		
	All flight software is classified as Class A software.		
	3.3.11.1 S/W Development Process		
110.	Requirement. Equipment provider shall follow the established processes and standards specified in the contractor developed S/W Management Plan (SMP).		
	3.3.11.2 S/W Requirement Trace		
111.	Requirement. Two-way requirement traces shall be established for each of the following: (a) JPL Radar Electronic Specification/ Contactor Developed Functional Requirement to S/W Requirements **(b)** S/W Requirements to S/W Design/Implementation **(c)** S/W Requirements to S/W acceptance Tests		
	3.3.11.2 S/W Reviews		
112.	Requirement. Contractor SQAE shall participate in all the S/W related reviews to the extent possible to assure adequacy, consistency and completeness of Contractor Radar Electronic Implementation Plan/ Radar Electronic Review Plan		
113.	Requirement. Contractor SQAE shall assure that the action items/defects resulting from the S/W reviews will be tracked and resolved.		
114.	Requirement. Contractor SQAE shall participate in and support the delivery manager in ensuring that all S/W deliverables as specified in the SMP, CDRLs, and DRDs will be verified and validated, prior to any S/W delivery review or S/W Review/Certification Requirement review (SRCR) review.		
	3.3.11.3 S/W Verification and Validation (V&V)		
115.	Requirement. Contractor shall have an independent review process that assures that the S/W V&V process will have adequate S/W test coverage.		
116.	Requirement. Contractor shall have an independent review process that analyze the test objectives and assure that entry and exit criteria for SW testing will be properly defined.		
117.	Requirement. Contractor shall have an independent review process that assures the S/W Acceptance Test shall cover the following:		

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	(a) Stress testing is adequate. (b) Reused S/W is tested in the Radar Electronic operating environment. (c) Fault Protection functions are adequately tested		
118.	Requirement. All the following items of the S/W and firmware destined for Qualification, Protoflight, Flight, Flight Spares, shall be subjected to Contractor SQA evaluations: (a) Accuracy of as-built product identification (b) Proper Test Plan/Procedures/Reports have been released (c) Installation Manual (d) List of open/closed PFR or liens against this delivery		
119.	Requirement. JPL software quality assurance verification of the software traceability matrix shall be performed to ensure that requirements are correctly applied and that critical mission software has been appropriately tested.	JPL Flight Project Practices (FPP), Rev. 5: Paragraph 7.3.5	
	3.3.11.4 S/W Configuration Management		
120.	Requirement. SQAE shall ensure that S/W CM will be performed through out S/W life cycle: (a) Contractor SQAE shall perform this function prior to S/W SRCR (b) JPL SQAE shall perform this function after S/W SRCR		
	3.3.11.5 S/W Engineering Change Request		
121.	Requirement. SQAE shall participate in assessing the impact of the S/W ECRs: (a) Contractor SQAE shall perform this function prior to S/W SRCR (b) JPL SQAE shall perform this function after S/W SRCR		
	3.4 Materials and Processes		
	3.4.1 Selection of Materials and Processes		
122.	Requirement. All materials and processes shall be qualified for the application in which they are used. In the event that the designer does not have appropriate data to indicate the suitability of a material or process, a qualification/evaluation test plan shall be generated and submitted to the JPL M&P Engineer and the MTO Product Assurance Manager for approval.		

ID	Mars Telecom Orbiter Mission Product Assurance Requirements	Reference	Comments
	3.4.1.1 Submittal of Material Identification and Usage Lists (MIUL)		
123.	Requirement. All materials shall be identified on a MIUL. Each MIUL shall contain the information described in JPL MIUL form. Project M&P shall review and approve all MIUL.		(1) Contractor can use JPL M&P form or an equivalent form approved by JPL M&P engineer. (2) This requirement does not apply to the electronic and electrical parts.
	3.4.1.2 Material Usage Agreements (MUA)		
124.	Requirement. For materials that do not meet MTO requirements, a MUA shall be required. For JPL-designed hardware: (a) Cognizant engineer shall submit MUAs to the Mars Telecom Orbiter M&P Engineer for approval. For contractor-designed hardware; (a) Contractor Cognizant engineer shall prepare MUAs for review and approval of the contractor M&P Engineer and (b) All contractors approved MUAs shall then be submitted to the JPL M&P Engineer for final approval. If approval is not granted and use is still desired, a waiver request shall be submitted to JPL M&P by the JPL cognizant engineer or contractor for review and risk assessment.		
	3.4.2 Material Selection		
	3.4.2.1 Material out-Gassing		
125.	Requirement. Material thermal vacuum stability and outgassing behavior shall be compatible with the mission environment and shall not adversely affect mission performance. Materials shall meet the requirements of JSC-	JPL STD-00009 and NASA document RP-1124	

ID	Mars Telecom Orbiter Mission Product Assurance Requirements	Reference	Comments
	SP-R-0022A. Only those organic materials with a total mass loss (TML) that does not exceed 1.00 percent and a collected volatile condensable mass (CVCM) that does not exceed 0.10 percent, when tested in accordance with ASTM E595 or contractor equivalent procedures, shall be considered for use. Some materials that meet JSC-SP-R-0022A may not be satisfactory, particularly in areas that are extremely sensitive to contamination. In such instances, special treatments, such as prolonged thermal-vacuum bakeouts, shall be employed to ensure that material outgassing will not adversely affect project mission performance. Such thermal-vacuum bakeout procedures shall be developed with and have the approval of the Project Contamination Control Engineer.	provide lists of materials that meet the out-gassing requirements.	
	3.4.2.2 Hazardous Materials		
126.	Requirement. All materials that are exposed to toxic or hazardous fluids shall be evaluated for compatibility with the fluid in their application. All materials that are exposed to the fluid shall be rated compatible in accordance with MSFC-HDBK-527/JCS-09604.		A hazardous fluid is any fluid that could chemically or physically degrade the system or cause an exothermic reaction. (2) Existing data showing compatibility may be used if approved by the Mars Telecom OrbiterMaterials Engineer.
	3.4.2.2 Flammable Material		
127.	Requirement. Materials shall be noncombustible or self-extinguishing and shall conform to the flammability requirements of NASA-STD-6001. Rationale for use of and acceptability of flammable materials in usage over 454 gm (1 lb.) or 30.5 cm (12 in.) shall be submitted in a MUA.		
128.	Requirement. Where flammable materials must be used, the standard	NASA-STD-6001	

ID	Mars Telecom Orbiter Mission Product Assurance Requirements	Reference	Comments
	hazard elimination and control requirements shall apply: (a) Two failure tolerance on ignition sources, (b) Physical separation of the flammable material from potential ignition sources, and (c) Elimination of flame propagation paths		
	3.4.2.3 Galvanic Corrosion		
129.	Requirement. In applications where dissimilar metals will be in contact, the metals shall be compatible with regard to galvanic corrosion. Methods to minimize the potential for corrosion shall be implemented. MIL-STD-889 shall be used as a guideline for controlling dissimilar metal contacts.		
	3.4.2.4 Stress Corrosion Cracking		
130.	Requirement. Only materials rated A or B in accordance with MSFC-HDBK-527/JSC-09604, or materials per Table I and II of MSFC-SPEC-522, shall be used.		(1) Use of Table III, or "C" rated, materials (or materials not listed in MSFC-SPEC-522 or MSFC-HDBK-527/JSC-09604) require, approval by the Mars Telecom Orbiter Materials & Processes Engineer.
	3.4.2.5 Shelf Life		
131.	Requirement. All materials with shelf-life sensitivity shall be used within their shelf-life limits. Extending the shelf-life of a material shall be according to the recommendation of the suppliers. If there is no supplier's recommendation available and the extension of shelf-life is necessary, an agreement shall be sought between Contractor Materials engineer and JPL Materials Engineer.		
	3.4.2.6 Magnetic Materials		

ID	Mars Telecom Orbiter Mission Product Assurance Requirements	Reference	Comments
132.	Requirement. The use of magnetic materials shall be limited, as necessary, to meet spacecraft or instrument magnetic requirements.		
	3.4.2.7 Radiation Resistance		
133.	Requirement. Materials used for flight hardware shall be able to withstand the radiation environment specified in the MTO Environmental Requirements Document with less than twenty percent degradation in their applicable properties over the life of the mission.	JPL D-26405, “Mars Telecom Orbiter Preliminary Environmental Requirements Document”	
134.	Requirement. In applications where the estimated damage dosage exceeds the twenty percent degradation level, or greater in available test data, shielding shall be used.		
135.	Requirement. Materials selected for MTO shall be demonstrated to be compatible with the following environments in the area in which they are exposed: (a) vacuum ultraviolet, (b) ultraviolet, (c) gamma ray, (d) electron and proton radiation In critical areas where no data exists MTO M&P engineer shall determine if testing is required.		
	3.4.2.8 Electrostatic Discharge (ESD)		
136.	Requirement. Materials shall (a) Be non-charging and evaluated to determine that ESD characteristics are compatible with MTO electrical requirements per JPL D-1348 and (b) Have its external surface resistivity not exceeding 10 MΩ / inch and must have ground path.		
	3.4.2.9 Fungi Attack		
137.	(a) Requirement. Flight hardware shall be designed so that materials are not nutrients for fungi except when used in permanent hermetically sealed assemblies and other accepted and qualified parts. Other	MIL-STD-810	

ID	Mars Telecom Orbiter Mission Product Assurance Requirements	Reference	Comments
	necessary fungi nutrient material applications shall require treatment by a method which will render the resulting exposed surface fungi resistant. The criteria for the determination of fungi and moisture resistance shall be those contained in MIL-STD-810.		
	3.4.2.10 Electrical Arc Track Resistance		
138.	Requirement. Electrical wire insulation, wire accessories and materials in contact with electrical circuitry shall be capable of withstanding arc tracking due to electrical discharges.		(1) Use of materials susceptible to arc-tracking requires JPL approved MUA. Materials shall be selected to minimize the possibility of arc-track formation, and the power in these areas limited.
	3.4.3 Lubricant		
139.	Requirement. Lubricant used in flight hardware shall not (a) Contaminate critical adjacent hardware by out-gassing (b) Surface creep or natural wetting and wicking of the lubricants		
140.	Requirement. Graphite, or lubricants with significant amounts of graphite, shall not be used in flight hardware		
	3.4.4 Metal Migration and Whisker Growth		
141.	Requirement. Metal migration has been reported for silver, gold, copper and tin on devices such as integrated circuits and circuit boards. Metal migration occurring electrolytically involves: (1) electrodissolution; (2) ion transport; and (3) electrodeposition. The metallic material is oxidized, producing ions that are transported through an electrolyte by electrical migration, diffusion, or convection. Cathodic reduction of the metal ions then occurs at dendritic nucleation sites. Failure is caused by the resulting conductive path formed across the dielectric between biased		

ID	Mars Telecom Orbiter Mission Product Assurance Requirements	Reference	Comments
	electrodes. This phenomenon shall be taken into consideration in electronic applications		
142.	Requirement. Whiskers can grow on tin, zinc, cadmium, and silver and can grow long enough to short out circuitry. Whisker growth is a form of induced recrystallization related to metallurgical imperfections and occurs under the influence of stress. Use of these materials in electronic applications shall be monitored and modified (e.g., with additives or substitution of alloys for pure metals) to avoid the phenomenon of whisker growth.		
	3.4.5 Design Allowable for Structural Parts		
143.	Requirement. Material property allowables contained in MIL-HDBK-5 and the properties contained in MIL-HDBK-17 shall be used for structural analysis.	MIL-HDBK-5 MIL- HDBK-17	
144.	Requirement. Prior approval of MTO M&P engineer is required for use of other sources of material strength or mechanics data.		
145.	Requirement. A-basis allowables shall be used for pressure vessels and for all metallic structures		
146.	Requirement. A-basis allowables shall also be used for structures where failure of a single load path would result in loss of structural integrity.		
147.	Requirement. Use of B-basis allowables shall require JPL Project M&P approval for redundant structures.		
	3.4.6 Fracture Critical Fasteners		
148.	Requirement. Fasteners shall be selected from the JPL Preferred Fastener List (PFL) contained in JPL STD-00009, or contractor equivalent. All externally threaded fasteners used for flight applications shall be certified. Fasteners used in structural applications shall have critical certification as described in SPI-4-11-8. Exceptions shall be submitted to the JPL Fastener Specialist for approval		(1) Critical certification requires documentation of chemical and physical test results traceable to both heat and lot numbers.

ID	Mars Telecom Orbiter Mission Product Assurance Requirements	Reference	Comments
149.	Requirement. Where fasteners are used in critical applications, document FS 511316 "Detail Specifications for Qualification of Critical Fasteners" shall be followed. Fasteners used in non-structural applications shall have, as a minimum, a Certificate of Conformance.		
	3.4.7 Traceability		
	3.4.7.1 Material		
150.	Requirement. Traceability of all materials incorporated into flight hardware shall be maintained. Records of material manufacturer, date of manufacture, batch and lot identification numbers, applicable materials and process specifications, expiration dates, and purchase order numbers shall be recorded.		
151.	Requirement. For the acceptance and traceability of flight bulk materials, including materials received on spools, in bottles, cans or kits, Quality Assurance Procedure QAP 44.10, Receiving Inspection and Identification of Flight Bulk Materials, shall be followed.	QAP 44.10	
	3.4.7.2 Fastener Traceability		
152.	Requirement. All externally threaded fasteners used for flight applications shall be certified. Fasteners used in structural applications shall have critical certification, requiring documentation of chemical and physical test results traceable to both heat and lot numbers, as described in JPL DocID 61256.	JPL DocID 61256	
153.	Requirement. Fasteners used in non-structural applications shall have, as a minimum, a certificate of conformance..		
	3.4.8 Welding		

ID	Mars Telecom Orbiter Mission Product Assurance Requirements	Reference	Comments
154.	Requirement. All welding operators on automatic, semi-automatic, or manual welding shall be qualified accordance with AMS-STD-1595 or a qualification procedure approved by the Mars Telecom Orbiter Materials Engineer.	AMS-STD-1595	
155.	Requirement. Weld rod or wire used as a filler metal on structural parts shall be fully certified and documented for composition, type, heat number, manufacturer, and supplied to provide positive traceability to the end use item.		
156.	Requirement. All fracture critical welds shall be non-destructively inspected per the requirements of NASA-STD-5003.	NASA-STD-5003	
	3.4.9 Non-Destructive Inspection		
157.	Requirement. Non-Destructive Evaluation (NDE) shall be conducted on highly stressed and mission or safety critical items. The Mars Telecom Orbiter Materials Engineer shall review NDI specifications.		
158.	Requirement Non-destructive inspection (NDI) techniques shall meet the requirements of MIL-I-6870 (or contractor equivalent) for magnetic particle, radiographic, eddy current, and ultrasonic inspection. Dye penetrant inspection shall meet the requirements of ASTM E1417 (or contractor equivalent). Etching of 0.0002 to 0.0004 inches prior to inspection is required. Specifications shall be reviewed by the JPL Project M&P Engineer.	MIL-I-6870 ASTM E1417	
	3.4.10 Alerts		
159.	Requirement. A GIDEP review shall be performed with results reported at PDR, CDR, and pre-ship on alerts affecting parts. Materials used in Mars Telecom Orbiter Flight Hardware that are identified in a Government/Industry Data Exchange Program (GIDEP), NASA Safety, or JPL Quality Alerts shall be evaluated for relevance to the Mars Telecom Orbiter.		
	3.5 Cleaning and Contamination Control		
160.	Hardware providers shall submit a Contamination Control Plan for review and approval by the JPL MTO Project Contamination Control Engineer which shall detail the following : (a) Internal and external cleanliness requirements related to, and		

ID	Mars Telecom Orbiter Mission Product Assurance Requirements	Reference	Comments
	derived from, mission performance requirements. (b) Interior and exterior cleanliness levels to be achieved at BOL (beginning of life—At completion of upper stage separation/CCAM maneuver.) (c) Methods and schedules for verification of interior and exterior cleanliness requirements. (d) External cleanliness requirements to be maintained during ground processing—integration with spacecraft, space vehicle environmental testing, launch vehicle integration. (e) The need for any required purges (f) The need for any unit-specific contamination control measures or environments required for maintaining cleanliness during ground processing.		
161.	Requirement. All hardware shall be maintained in a Class 100,000 environment.		
162.	Requirement. Materials used in MTO hardware shall be insensitive to the NASA approved cleaning agents. The JPL contamination control engineer shall approve all cleaning procedures prior to use.		
163.	Requirement. Vacuum Stability - All materials used in the construction of the space vehicle shall meet or better the following criteria: < 1 percent total mass loss (TML) and < 0.1 percent collected volatile condensable material (CVCM)—as tested per ASTM-E595.* * NOTE: This requirement is the minimum criterion for space rated materials. Other, more stringent, vacuum stability requirements may be levied on individual materials on the basis of mission-specific analysis. Such additional requirements may necessitate measures such as thermal-vacuum bakeout, encapsulation (with an impermeable material), material substitution, or design alteration to meet mission-specific requirements.		
164.	Requirement. Exterior Surface Cleanliness-A schedule for cleanliness verification shall be included in the unit-specific (spacecraft, instrument payload, launch vehicle) contamination control plan. In general, exterior surface cleanliness requirements are to be verified before last access to areas that will become inaccessible at higher levels of assembly and before and after significant system-level events such as instrument-spacecraft integration, space vehicle environmental test series, and TBD.		

<table>
<tr><th>ID</th><th>Mars Telecom Orbiter Mission Product Assurance Requirements</th><th>Reference</th><th>Comments</th></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>165.</td><td>Requirement : Particulate (TBR) -The exterior surfaces of all hardware delivered for flight system integration shall be meet the criteria of Visibly Clean—Level II (also known as VC-II, VC-HS, or Visibly Clean-Highly Sensitive) as defined in the table below :

Flight System Surface Cleanliness—Visibly Clean—Definitions
<table>
<tr><td>Visibly Clean level 2
VC-L2</td><td>Surface cleanliness inspection level 2 specifies an incident light of 1080 lux to 1340 lux (100 to 125 foot-candles) at the surface. The surface to be inspected shall be visibly clean when observed by the unaided (except for corrected vision) eye at a distance of 15 cm to 45 cm (6 to 18 inches).</td></tr>
<tr><td>Visibly Clean level 2 plus UV
VC-L2+UV</td><td>The absence of all visible particulate and molecular contaminants when observed at a distance of 15 cm to 45 cm (6 in to 18 in) with an incident surface illumination of (1080 lux to 1340 lux (100 FC to 125 FC). and ultraviolet light at a wavelength of 365 nm (UV-A) and a minimum irradiance of 800 $\mu W/cm^2$ at 15 cm (6 in).</td></tr>
</table></td><td></td><td>TBR—To be revised. Requirements carrying this annotation shall be considered as tentative and used for planning purposes only.</td></tr>
<tr><td>166.</td><td>Requirement. Molecular—(TBR) - Exterior surfaces of all hardware delivered for flight system integration shall be meet the meet the following criterion: <Level A (1.0 $\mu g/cm^2$) per MIL-STD-1246C.</td><td></td><td>TBR—To be revised. Requirements carrying this annotation shall be considered as tentative and used for planning purposes only.</td></tr>
<tr><td></td><td>3.6 SAFETY REQUIREMENTS</td><td></td><td></td></tr>
<tr><td></td><td>3.6.1 General Safety Design Requirements</td><td></td><td></td></tr>
<tr><td></td><td>The number of design inhibits required to prevent an overall system failure or mishap is based on the failure or mishap result.</td><td></td><td></td></tr>
<tr><td></td><td>3.6.1.1 Catastrophic Hazard</td><td></td><td></td></tr>
</table>

ID	Mars Telecom Orbiter Mission Product Assurance Requirements	Reference	Comments
167.	Requirement. If a system failure may lead to a catastrophic hazard, the system shall have at least three inhibits (dual fault tolerant).		A catastrophic hazard can result in the potential for a disabling or fatal personnel injury or for loss of facilities or equipment (e.g., ground processing facility, launch vehicle, other payload).
	3.6.1.2 Critical Hazard		
168.	Requirement. If a system failure may lead to a critical hazard, the system shall have at least two inhibits (single fault tolerant).		A critical hazard can result in damage to equipment, a nondisabling personnel injury or in the unscheduled use of safing procedures that affect operators/operation of the MTO.
	3.6.1.3 Marginal Hazard		
169.	Requirement. If a system failure may lead to a marginal hazard, the system shall have at least a single inhibit (no fault tolerant).		All other hazards.
	3.6.1.4 Return to Safe State		
170.	Requirement. Systems shall return to a safe state with the loss of inhibit.		
	3.6.1.5 Independence and Verifiable		
171.	Requirement. The states of all inhibits shall be independent and verifiable unambiguously.		
	3.6.1.6 Electrical and Mechanical Hardware		

ID	Mars Telecom Orbiter Mission Product Assurance Requirements	Reference	Comments
172.	Requirement. Design inhibits shall consist of electrical and mechanical hardware.		
	3.6.1.7 Operator Controls		
173.	Requirement. Operator controls shall not be considered a design inhibit.		Operator controls are considered a control of an inhibit.
	3.6.1.8 Systems Safety Requirements		
174.	Requirement. MTO shall comply with JPL D-560.	JPL D-560	
	3.6.1.9 Range Requirements		
175.	Requirement. MTO shall comply with appropriate range requirements.		In the U.S. the range requirements are defined in EWR 127-1.
	3.6.2 Material Handling Equipment		
176.	Requirement. MHE used to handle hardware should have connector (e.g., pin, bolt, lug, rivet) and weld designs that are single fault tolerant against catastrophic failure.		
177.	Requirement. The use of SFP welds shall be prohibited.		If the use of SFP welds cannot be avoided, designs are to be easily inspected and identified as SFP welds in the drawings.
178.	Requirement. SFP components and welds shall be designed to be accessible for initial and periodic NDE.		
	3.6.2.2 Sling Assemblies Used to Handle Hardware		

ID	Mars Telecom Orbiter Mission Product Assurance Requirements	Reference	Comments
179.	Requirement. All slings shall be designed with an ultimate factor of safety of 5 or higher.		
180.	Requirement. All synthetic slings shall be designed with an ultimate factor of safety of 10 or higher.		
181.	Requirement. Natural fiber rope or natural fiber web slings shall not be used.		
182.	Requirement. Carbon steel or wrought iron chain slings shall not be used.		
183.	Requirement. Wire rope slings shall be formed with swaged or zinc poured sockets or spliced eyes.		
184.	Requirement. Wire rope clips or knots shall not be used to form slings.		
185.	Requirement. Rotation resistant rope shall not be used for fabricating slings.		
	3.6.2.3 Lifting Structure / Fittings on Flight H/W		
186.	Requirement. Lift fittings such as lugs and plates permanently attached to flight hardware shall be designed so that the loss of one fitting and/or structure will not result in the dropping of the load.		
187.	Requirement. If the requirement within 3.6.2.3 cannot be met, the minimum ultimate factor of safety shall be 1.5.		
	3.6.3 Non-Ionizing Radiation Sources		
	3.6.3.1 Radio Frequency Emitter Design Standards		
188.	Requirement. Radio frequency (RF) emitters shall be designed to ensure that personnel are not exposed to hazard levels in excess of the following: (a) Continuous exposure (8 hour/day, 40 hour/week): < 1 mW/ cm^2		

ID	Mars Telecom Orbiter Mission Product Assurance Requirements	Reference	Comments
	(b) Emergency exposure (< 1 hour/24-hour period): < 10 mW/cm^2		
	3.6.3.2 Radio Frequency Emitter Design		
189.	Requirement. RF emitters shall be designed and located to allow test and checkout without presenting a hazard to personnel, ordnance, or other electronic equipment.		
190.	Requirement. Where necessary, interlocks, interrupts, or other safety devices shall be provided to protect operating personnel and exposed initiators during ground operations.		
191.	Requirement. Fail-safe systems shall be incorporated so that inadvertent operation of an RF emitting system is prevented.		Fail-safe system is defined as a system which ensures hazardous operations and/or conditions are precluded. Power is not necessary for the fail-safe system.
192.	Requirement. Electro-explosive subsystems shall not be exposed to RF radiation that is capable of firing the electro-explosive device (EED) by pin-to-pin bridge wire heating or pin-to-case arcing.		
193.	Requirement. RF power at the EED shall not exceed 20 dB below the pin-to-pin direct current (DC) no-fire power of EED.		
	3.6.4 Hazardous Materials		
	3.6.4.1 Hazardous Materials Selection Criteria		
194.	Requirement. The MTO Systems Safety Engineer shall approve flammable liquid or material before use.		
195.	Requirement. Materials that will not burn readily upon ignition shall be used.		
196.	Requirement. The MTO Systems Safety Engineer shall approve toxic liquid or material before use.		

ID	Mars Telecom Orbiter Mission Product Assurance Requirements	Reference	Comments
197.	Requirement. Materials that will not give off a toxic gas if ignited shall be used.		
198.	Requirement. Materials, including leakage, shall not come in contact with a non-compatible material that can cause a hazard.		
199.	Requirement. Hazardous materials shall not retain a static charge that presents an ignition source to ordnance or propellants or a shock hazard to personnel.		
200.	Requirement. Hazardous pressure systems shall be designed so that depressurization and drain fittings are accessible and do not create a personnel or equipment hazard for off-loading hazardous fluids.		(1) This requirement is intended for contingency safing operations. (2) Goal. It should be possible to offload these pressure systems at any point after pressurization or loading, including the ability to offload all systems at the launch pad without de-mating of the spacecraft from the launch vehicle or any other disassembly of vehicle systems.
	3.6.5 Electrical and Electronic Ground Support Equipment and Flight Hardware Power Cut Off		
201.	Requirement. All Electrical and Electronic Ground Support Equipment (EGSE) and flight hardware shall have a means to cut off power prior to installing, replacing, or interchanging units, assemblies, or portions thereof.		
	3.6.5.1 EGSE and Flight Hardware Power Transient		

ID	Mars Telecom Orbiter Mission Product Assurance Requirements	Reference	Comments
202.	Requirement. Safety critical systems shall be protected against power transients from facility power.		
	3.6.5.2 EGSE and Flight Hardware Connectors		
203.	Requirement. If a hazardous condition can be created by mismating or reverse polarity, connectors shall have alignment pins, keyway arrangements, or other means to make it impossible to incorrectly mate.		
	3.6.5.3 EGSE and Flight Hardware Grounding, Bonding, and Shielding		
204.	Requirement. Equipment shall be designed and constructed to ensure that all external parts, shields, and surfaces, exclusive of radiating antennas and transmission line terminals, are at ground potential.		
205.	Requirement. Shields shall not be used as current carrying ground connections, except for coaxial cables.		
206.	Requirement. Circuits that operate safety critical or hazardous functions shall be protected from the electromagnetic environment to preclude inadvertent operation.		
	3.6.5.4 EGSE and Flight Hardware Batteries		
207.	Requirement. Battery connectors shall be designed to prevent reverse polarity.		
208.	Requirement. Diodes shall be used to prevent reverse current.		
	3.6.5.5 EGSE Switches and Controls		
209.	Requirement. A clearly labeled main power switch and power indicator light located on ground support equipment shall cut off power to all circuits in the equipment.		
210.	Requirement. A power indicator light shall be provided.		
	3.6.5.6 EGSE Circuit Protection		
211.	Requirement. Fuses, circuit breakers, and other protective devices shall be used for EGSE primary circuits.		

ID	Mars Telecom Orbiter Mission Product Assurance Requirements	Reference	Comments
212.	Requirement. Protective devices shall be connected to the load side of the main power switch unless neutral power sensing is essential for proper protection of the equipment.		
213.	Requirement. Each redundant EGSE circuit shall have its own circuit breaker or fuse.		
214.	Requirement. Each circuit shall not have the capability to inhibit by loss of control more than one safety critical control device.		
	3.6.5.7 Flight Hardware Batteries		
215.	Requirement. Flight battery cases shall be designed to an ultimate safety factor of 3 to 1 with respect to worst case pressure build-up for normal operations.		
216.	Requirement. Sealed batteries shall have pressure relief capability unless the battery case is designed to a safety factor of at least 3 to 1 based on worst case internal pressure.		
	3.6.6 Seismic Design		
217.	Requirement. Equipment shall be restrained to restrict movement and withstand a seismic event.		
	Requirement. Restraints shall be designed to withstand loads as described in the following paragraphs: (a) Restraints shall be designed to react to accelerations equivalent to a horizontal force of two times the equipment weight, applied through its center of gravity, in the direction in which movement is restricted. (b) Restraints shall prevent tip over, collapse, excessive deflection, or sliding.		
	3.6.7 Mishap Reporting		
218.	Definition. A mishap which causes personnel injury more than first aid severity, and/or property damage equal to or greater than $1,000, which		

ID	Mars Telecom Orbiter Mission Product Assurance Requirements	Reference	Comments
	arises from work performed under this Project/Contract shall comply with NPG 8621.1		
219.	Requirement. In accordance with NPG 8621.1, all Contractor employees are responsible for reporting mishaps immediately. In the event that a mishap is serious (defined above), the Contractor shall immediately notify JPL Project Management. All mishaps shall be documented on a Mishap Report (JPL Form 0554-S or equivalent) and forwarded to JPL.	NPG 8621.1 JPL Form 0554-S	
220.	Requirement. When a mishap occurs, an Initial Mishap Report shall be sent to JPL within 24 hours of the mishap.		
	3.6.8 Lifting Device		
221.	Requirement. The testing, inspection, maintenance, operational, and operator and rigger certification/ re-certification / licensing requirements apply to new and existing lifting devices and equipment. All lifting devices and equipment shall comply with NASA Standards.	NASA-STD-8719.9	
	3.7 ORBITAL DEBRIS		
	3.7.1 General Mitigation		
222.	Requirement. MTO shall analyze the mitigation of orbital debris.	NSS 1740.14	

Appendix A - Forms

Materials Usage Agreement!	USAGE AGREEMENT NO.	REVISION A	PAGE OF

PROJECT	SUBSYSTEM	ORIGINATOR	ORGANIZATION
DETAIL DRAWING(S)	USING ASSEMBLY(S)	ITEM DESCRIPTION	ISSUE
MATERIAL	TRADE NAME	SPECIFICATION	MANUFACTURER

THICKNESS	WEIGHT	EXPOSED AREA	LOCATION	ENVIRONMENT		
			HABITABLE ☐ NONHABITABLE ☐	PRESSURE	TEMPERATURE	MEDIA

APPLICATION

RATIONALE

ORIGINATOR	PROGRAM MANAGER ()	DATE
	(PROJECT)	DATE

Materials Usage Agreement!	USAGE AGREEMENT NO.	REVISION	PAGE 2 OF
PROJECT	SUBSYSTEM	ORIGINATOR	ORGANIZATION
DETAIL DRAWING(S)	USING ASSEMBLY(S)	ITEM DESCRIPTION	ISSUE
MATERIAL	TRADE NAME	SPECIFICATION	MANUFACTURER

THICKNESS	WEIGHT	EXPOSED AREA	LOCATION	ENVIRONMENT		
			HABITABLE ☐ NONHABITABLE ☐	PRESSURE	TEMPERATURE	MEDIA

MATERIALS ENGINEERING EVALUATION

Radiation Exposure:

APPROVED ☐	DISAPPROVED ☐	M&P SPECIALIST APPROVAL (PROJECT)	SYSTEM SAFETY APPROVAL

REMARKS

PROBLEM FAILURE REPORT (PFR)	PFR # Z79708
PFR Title	
Project TINY TEST - TT Status OPEN	Day of Year and Time of Day Day: 065 Hr: Min:
Problem/Failure Date (mm/dd/yyyy) 03/06/2003 — Last Processed 03/06/2003	Log#
Report Type: Formal/Prelaunch - FP — SC or Instrument ID — Grnd / Test, Eng. Model, Flight, Clear	Hardware, Software, Clear
Originator (Discovered By) (last, first mi -or- badge #) DANESH, PARVIZ — Date (mm/dd/yyyy) 03/06/2003	Assigned To (Cog-E): - no selection made - Available Assignees: Known Assignees... Add New Assignee: (badge #) Badge Lookup

SUBSYSTEM

Tier	Reference Designation	Nomenclature	Serial Number	Oper. Time	Operating Units
0	Subsystem: V4.3 - PFOC VERSION 4.3 Problem Area:				
1					
2					
3					

DESCRIPTION

Description of Problem/Failure

OVWM

Reporting Location

Problem/Failure Noted During

Specific Environment

Procedure	Revision	Paragraph

SUBMIT | UNDO CHANGES

VERIFICATION

Verification and Analysis

Cause of Problem/Failure	
Person Completing This Section	Date (mm/dd/yyyy)

PART DATA - EPINS						
Piece Part Name	Part #	Serial #	FA Log #	Circuit Desig.	Mfr. Code	Defect

CORRECTIVE ACTION

Corrective Action Taken

Disposition of Subsystem or Assembly	Effectivity All Units This Unit Other

SUBMIT UNDO CHANGES

CODES & RATINGS			
Lessons Learned Candidate Y N	Alert Concern Y N	Mission Critical Failure Y N	STS Criticality Unassigned -
Personnel Safety Y N	Hardware Safety Y N	Safety Status SS has not reviewed yet. -	
See PFR	See ISA	Failure Effect Rating: 1 2 3	
ECR No.	Waiver No.	Failure Cause/ Corrective Action Rating: 1 2 3 4	
See Other			

SIGNATURES

	Signature (Format: last, first mi -or- badge #)	Date (mm/dd/yyyy)
Contractor		
Cognizant Engineer		
Section Manager		
System Engineer		
Test For New Signature Number 10		
Reliability Engineer		
Safety Engineer		
Product Assurance		
Instrument Manager		
Project Manager		

ISSUES

Issues

No previous issues recorded.

Enter Additional ISSUES Here...

NO ATTACHED DOCUMENTS ON FILE.

SUBMIT | UNDO CHANGES

CHANGE LOG

Changes

** CHANGELOG: Z79708 ***************************************
Changes made on 03/06/2003 at 13:47:25 by PDANESH
ROOT.SYSID was: "", now is: "PFR"
ROOT.PROJECT was: "", now is: "TT"
ROOT.PFR_NO was: "", now is: "Z79708"
ROOT.IS_PFR was: "NO", now is: "YES"
ROOT.ACTIVE was: "NO", now is: "YES"
ROOT.PFR_DATE was: "", now is: "03/06/2003"
ROOT.ORIGINATN was: "", now is: "03/06/2003"
ROOT.PEND_COG_E was: "NO", now is: "YES"
ROOT.NEED_MF_UP was: "NO", now is: "YES"
ROOT.SEF was: "", now is: "N"
ROOT.MCF was: "", now is: "N"
ROOT.VENDOR was: "", now is: "VEN"
ROOT.ORIGINATOR was: "", now is: "DANESH, PARVIZ"
ROOT.SUB_SYS was: "", now is: "V4.3"
ROOT.PHASE was: "", now is: "FP"
ROOT.AT_YEAR was: "", now is: "2003"
ROOT.AT_DAY was: "", now is: "065"
ROOT.DESCRIPTN was: "", now is: "OVWM"
ROOT.Y2K was: "", now is: "N"
PFR_UNIQ.PFR_NO was: "", now is: "Z79708"
HOBO.SYSID was: "", now is: "PFR"
HOBO.PROJECT was: "", now is: "TT"
HOBO.PFR_NO was: "", now is: "Z79708"
HOBO.PEND_COG_E was: "NO", now is: "YES"
HOBO.BADG_ASSN2 was: "", now is: "105143"

--end of change log--